Fundamentals of Teletypewriters Used in the Bell System

By E. F. WATSON

During the past few years the use of teletypewriters has become quite extensive in the Bell System. Simpler and cheaper machines have recently been made available for meeting the simpler service requirements and attachments have been designed to provide additional features for meeting more complex service requirements. This article discusses the fundamental principles and various features of the teletypewriter machines now in common use and explains the more important factors which have been controlling in their development.

WITH the growth of Teletypewriter Exchange Service and the general increase in the use of teletypewriters in private line services of various types, questions frequently asked are: How do teletypewriters operate? What is the "start-stop" system? Why is it used? What is a regenerative repeater?

This article will attempt to answer some of these questions and explain also the fundamental principles and features of teletypewriters and their auxiliary arrangements as now employed in the Bell System. These have been developed to meet the needs of customers for a typed or similar record form of communication and at the same time be suitable for operation in connection with the Bell System plant.

Code

For economical transmission over long distances it is fundamental that only a single wire or transmission channel be required to carry the signals. Furthermore, long experience with manual telegraphy on land lines has proved that reliable and efficient operation is secured by using not more than two conditions on the line, such as current and no current or positive impulses and negative impulses, as contrasted with the use of three or more conditions, or current values. The entire telegraph plant of the Bell System as well as practically all other land line telegraph systems have been built on this two-condition basis.

The familiar Morse code uses sequences of dots and dashes to represent the different characters of the alphabet and meet the above conditions. This code is not well adapted for teletypewriter control, however, since the signals for different characters vary widely in the time they require, from a single dot for the letter E to a combination of

several dots and dashes for some of the less frequently used letters or numerals.

For machine operation it has thus far appeared desirable in order to obtain simplest mechanisms and to obtain maximum operating speeds with low line signaling frequencies, to have the signals for the different characters of uniform length, that is, each contain the same number of time units. This condition is met by the five-unit code where each character is identified by the impulses in five units of time, and this is the code normally employed in Bell System teletypewriters. Each of the five units of this code may be either positive or negative, current or no current, or either of two values of current, and the permutations provided are 2^5 or 32. These are sufficient for the 26 letters of the alphabet, a space, carriage return and paper feed signals as well as case shifting signals to bring another set of characters into action so as to include numerals and punctuation marks. A chart of this code as used in Teletypewriter Exchange Service (TWX), is shown below.

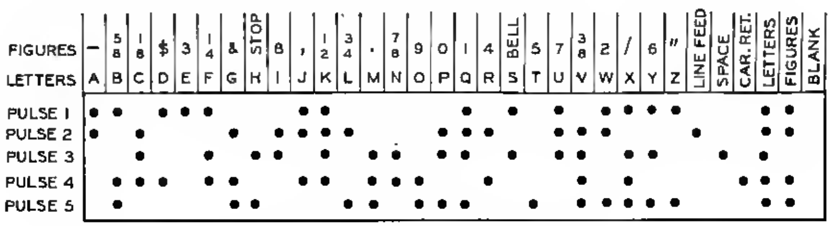

Fig. 1—Chart of five-unit TWX code.

The keyboard used for sending this code is shown below.

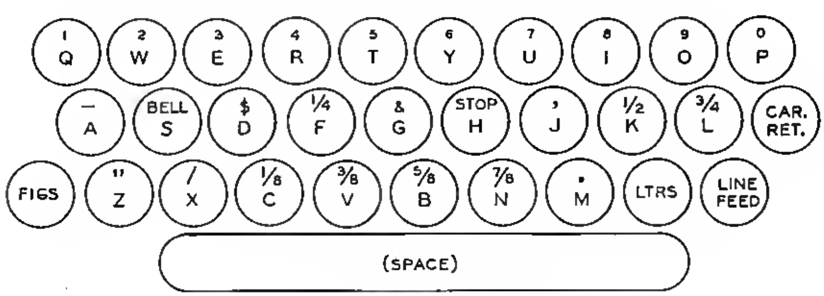

Fig. 2—Chart of TWX keyboard.

It will be noted that this keyboard is similar to the ordinary typewriter keyboard except that there are only three rows of keys instead of four as in the typewriter. In the typewriter keyboard, the lower three rows of keys are used ordinarily for small letters but when a shift

key is also operated they type the corresponding capital letters. The fourth or top row of keys carries the numerals and certain punctuation marks. The teletypewriter types capital letters but not small letters so that by using a shift or *Figures* key the upper case position of the letter keys is available for the usual punctuation marks and numerals. Thus only three rows of keys are required on the teletypewriter keyboard. The operation of the *Figures* key sends a signal causing the receiving machine to shift to upper case so that numerals and punctuation marks will be printed until a *Letters* or *Space* signal is sent which restores the machine to lower case.

Start-Stop System

For transmitting the signals of the five-unit code over a telegraph line, it is necessary to have some system of timing so that each of the five impulses may be properly received, identified and interpreted at each receiving station. The start-stop system is used for this purpose. One arrangement of this system using segmented distributors with revolving brushes, is illustrated in Fig. 3.

In this system both sending and receiving brush arms are normally at rest but are maintained under constant torque, tending to rotate them in the direction of the arrows, by constantly running motors driving them through friction clutches. Normally the line circuit is closed and carries current. When a key of the keyboard is operated to send a signal, the start magnet of the sending distributor is energised releasing the sending brush arm and allowing it to rotate. As this brush passes from the stop to the start segment, the line circuit is opened and this open signal transmitted to the receiving station where it causes energization of a start magnet which releases the receiving brush and allows it to rotate.

Both sending and receiving brush arms rotate at approximately the same speeds since they are driven from motors running at approximately the same speeds. These motors are either small synchronous motors driven from constant frequency commercial 60-cycle 110-volt power supply or by commutator type motors, equipped with centrifugal governors to hold them at approximately a constant speed, for use on other commercial a-c. or d-c. supplies.

Now as the sending brush arm sweeps over the sending face, the impulses of the five-unit code, as set up by the particular key depressed, will be transmitted over the line as shown in Fig. 4 for the letter A, and through the action of the rotating receiving brush, Nos. 1 and 2 current impulses will cause the energization of Nos. 1 and 2 selecting

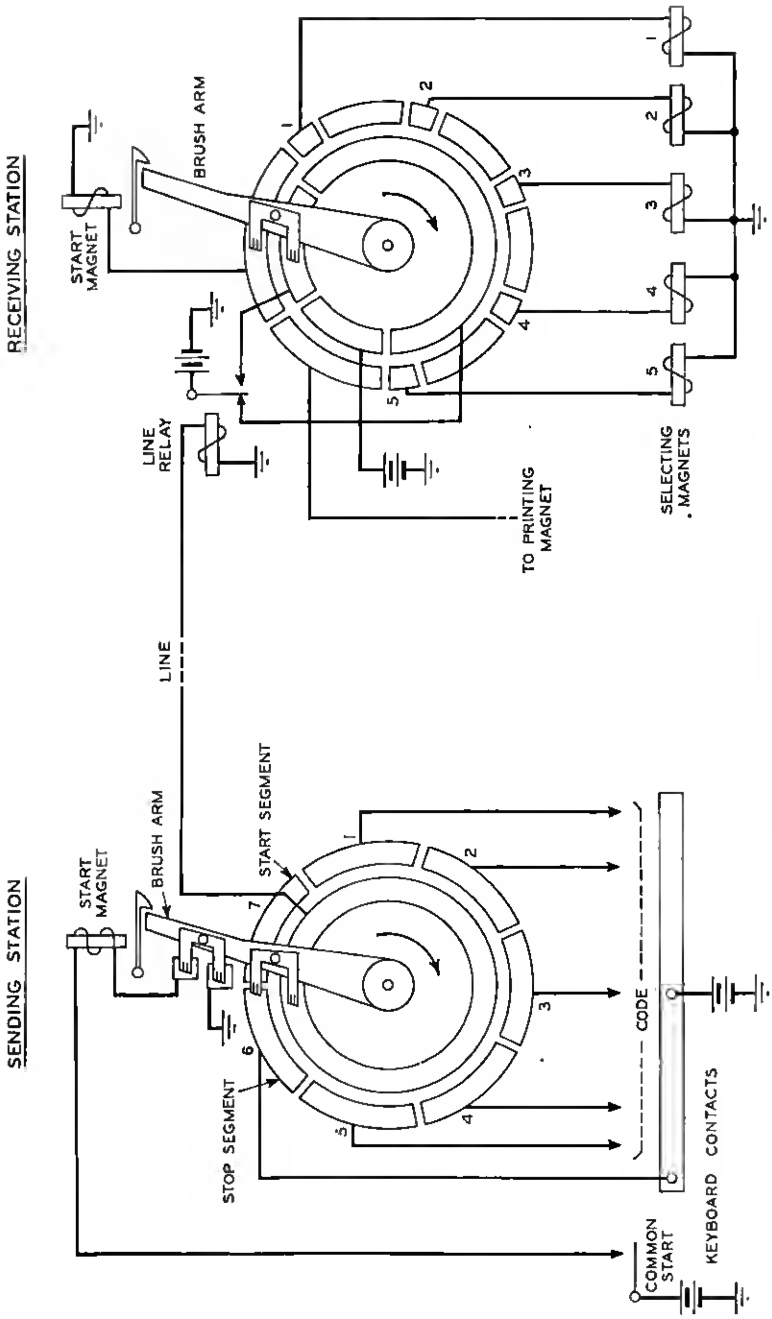

Fig. 3—Simplified diagram of start-stop system.

magnets while Nos. 3, 4 and 5 no-current impulses will not energize selecting magnets 3, 4 and 5.

Similarly other signals for other characters may be sent and received as permutations on the selecting magnets whose operation may in turn control the selection of an individual type bar to be operated to type the desired character.

While brush and segment distributors are shown above for purposes of illustration, in modern machines these are replaced by simple mechanical devices, sending contacts and a single receiving magnet, which function in the same manner but are cheaper, more reliable and easier to maintain.

Advantages of the start-stop system over other systems of timing include its simplicity, the fact that highly accurate speed regulation of the motors is not required, that to start a station it is only necessary to turn on the power, and that lag in the line signals due to time for propagation is automatically compensated for. The lag compensation

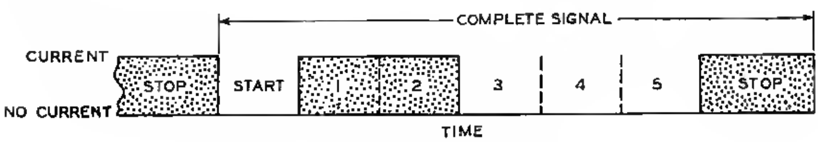

Fig. 4—Chart of line signal for letter A.

is automatic because the receiving distributor does not start until the start signal has been propagated and received and then the other signals always follow in a fixed definite time relation. This makes it possible to connect any number of stations to a single circuit and have them intercommunicating; that is, signals sent from any station will be received and printed at all other stations without requiring readjustments, regardless of the distances or circuit complications due to repeaters and the like intervening.

To illustrate one of these points further, it may be mentioned that with the start-stop system, if other distortions were not present, it would be theoretically possible to secure perfect operation without errors between two ideal distributors one of which was running either faster or slower than the other by as much as 7 or 8 per cent. This is because a correction is automatically made after each character is transmitted. Since some distortion of the signals is usually experienced in transmission, in order to maintain a large tolerance for such distortions, it is the usual practice to attempt to maintain the speed of each distributor within $\pm$ .75 per cent although a much

larger variation may be tolerated without causing errors except when it occurs simultaneously with an abnormally large line distortion.

In contrast with this, in a synchronous system such as employed in the usual "Multiplex Printer System," it is necessary that the speeds of distributors be very accurately maintained or errors in transmission will result. This is accomplished by controlling the driving motors from very accurate timing sources such as tuning forks, then testing the speed of the receiving distributor two or more times every revolution from the signals transmitted over the line from the sending distributor, and automatically correcting this speed as required. If it were not for this last mentioned correction in order to receive signals correctly on a two-channel multiplex system for a period of 15 minutes at a speed of 60 words per minute per channel, the receiving distributor speed would have to be held accurate within $\pm$ .002 per cent. In other words, in 15 minutes the receiving distributor would make about 5400 revolutions (60 words per minute $\times$ 6 revolutions per word $\times$ 15 minutes). At the end of the 15 minutes, if it were one-tenth of a revolution ahead or behind its correct position, a No. 3 pulse, for example, would be received on a No. 4 or No. 2 segment resulting in an error. Thus the limit would be that the receiving distributor could not run fast or slow by as much as one-tenth revolution in 5400 revolutions or roughly 2 parts in 100,000.

Tolerance for Distorted Line Signals

During transmission over long lines, telegraph signals may become badly distorted; that is, the dots and dashes may be considerably shortened or lengthened from their correct values. It is essential that the receiving distributors be capable of receiving and interpreting these signals without error. To accomplish this the receiving distributors are arranged so that they are sensitive for the reception of the selecting impulses only for a very short time at the middle of each impulse. The exact location of this sensitive period with relation to the incoming signals is adjustable in each receiving distributor so that it may have maximum tolerance for receiving distorted signals. This situation is illustrated in the diagram, Fig. 5, which shows a receiving distributor with the received signals under various conditions developed, and the sensitive points for the reception of the impulses indicated by small arrows.

It will be noted from this chart that the signals may be very badly distorted (theoretically up to nearly 50 per cent of a pulse length at either the front or rear end of a current pulse), without causing imperfect reception.

In the figure it will be noted that trace (a) shows a perfect signal with the arrows denoting the sensitive points for receiving each pulse located directly at the center of each of the pulses 1 to 5. This is a normal adjustment for a receiving distributor which, without change of this adjustment, must be able to tolerate the distortions of various kinds

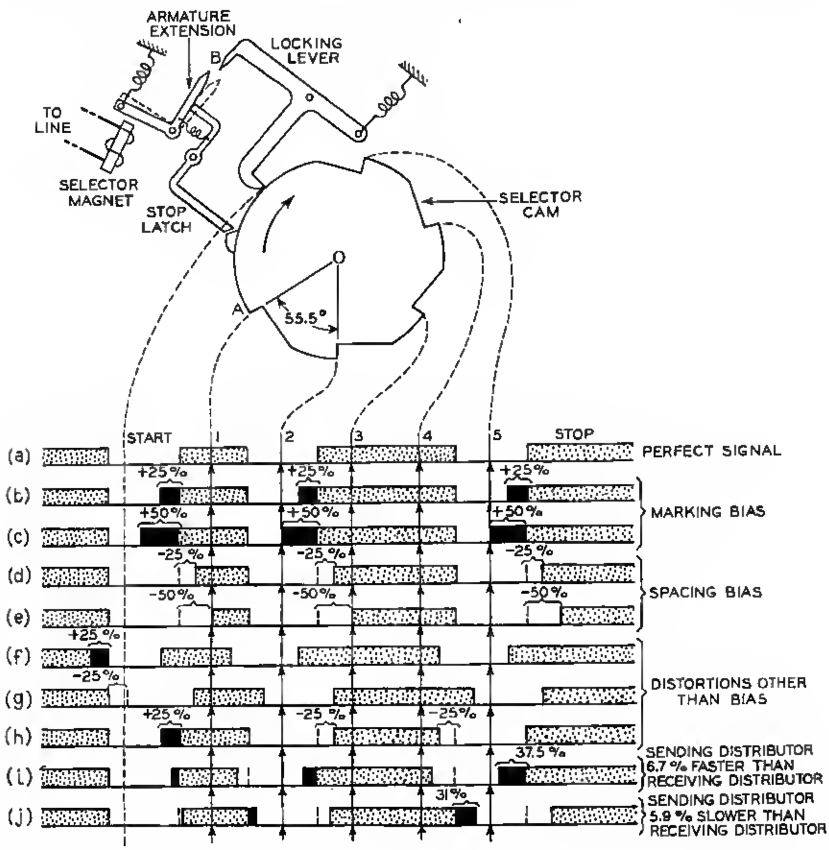

Fig. 5—Effect of distorted signals on reception.

experienced in service without failure to receive and properly identify each pulse as a No. 1, 2, 3, 4 or 5 pulse. The other traces illustrate certain types of distortions which may be experienced and the conditions existing for their proper reception with this adjustment. These traces will now be explained on a purely theoretical basis assuming an ideal receiving machine without mechanical or other imperfections.

Trace (b) shows the conditions in case of 25 per cent "marking bias" in the received signals; that is, each marking pulse has been lengthened

by 25 per cent of one pulse length. It will be noted that under these conditions each pulse will still be properly received and identified.

Trace (c) illustrates 50 per cent marking bias in the received signal, and at this point it will be noted that the No. 3 and stop pulses have been so elongated that they are just on the verge of being erroneously received and identified also as No. 2 and No. 5 pulses. This then is a theoretical limit for proper operation with marking bias without a readjustment of the receiving distributor.

Similarly traces (d) and (e) illustrate respectively the conditions when the received signals have 25 per cent and 50 per cent "spacing bias," that is each marking impulse has been shortened by this percentage of one pulse length. It will be noted that 25 per cent spacing bias can be easily tolerated but that with 50 per cent spacing bias the No. 1 and No. 3 pulses are on the verge of failure to be recorded. This then is a theoretical limit for spacing bias in the signals under this adjustment.

Traces (f) and (g) show the effect of 25 per cent marking and spacing distortions respectively on the rear end of the stop or front end of the start impulse, all other pulses remaining undistorted.

Trace (h) shows the effect of distortions on the selecting impulses alone. By combining this trace with traces (f) and (g) it will be seen that with 25 per cent distortion of the start pulse, 25 per cent distortion of the same sign is the limit for distortion on the front end of marking impulses, or 25 per cent distortion of opposite sign on the rear end of marking impulses. Thus for distortions other than bias, which are apt to affect both start and selecting impulses in the same signal, $\pm$ 25 per cent is the theoretical limit of allowable distortion.

Traces (i) and (j) show the effects of speed inaccuracies. From these it will be seen that theoretically the sending distributor could be about 8.9 per cent faster or 9.5 per cent slower than the receiving distributor before errors would be experienced.

In practical machines there are, of course, inaccuracies due to tolerances of manufacture, and other departures from the ideal so that the above mentioned theoretical limits are not reached. However, all machines used in the Bell System are required to tolerate a lengthening or shortening of the front end of any current impulse of at least 40 per cent of its length and with the same adjustment a lengthening or shortening of the rear portion of any current impulse of at least 35 per cent with the start pulse undistorted. Since bias is nearly always present to some degree in the received signals, and since as interpreted by the receiving distributor it affects only the front end of the current impulses as illustrated in traces (b), (c), (d) and (e) of Fig. 5, the

distributors are usually adjusted for maximum tolerance of front end distortions and then have ample tolerance for such distortions of the rear ends of the current impulses as are experienced under service conditions.

Regenerative Repeaters

As circuits become longer and more complex, eventually a point is reached beyond which signal distortion becomes so great that the signals cannot be reliably received without error. To overcome this

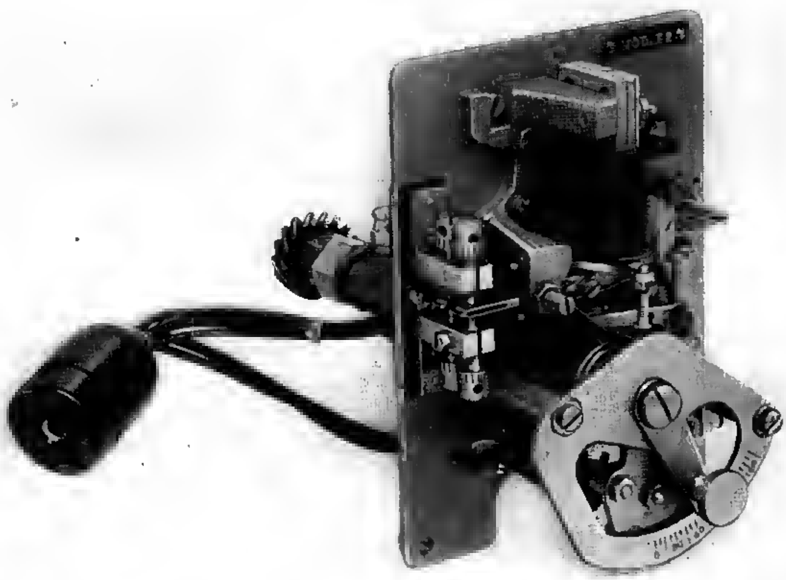

Fig. 6—Regenerator unit.

limitation a device known as a regenerative repeater may be inserted in the line at this point. It has a receiving mechanism similar in principle to the receiving distributor of a teletypewriter and will accurately receive and interpret any signals which a teletypewriter would accurately record. This receiving mechanism is interconnected with a retransmitting mechanism, or sending distributor, which retransmits the signals reshaped and reformed so as to be substantially free from distortion. In its latest form a one-way regenerative repeater consists of a receiving magnet and a set of transmitting contacts interconnected by some relatively simple mechanical parts driven from

a motor. A photograph of such a recently developed regenerative repeater unit is reproduced in Fig. 6.

By means of these regenerative repeaters reliable teletypewriter service may be extended to any desired distances so long as the signals in any one regenerative repeater section are not too badly distorted to permit reliable operation of that section alone. Several regenerative repeaters may be operated in tandem on a single very long circuit if required and in fact a number of very difficult long circuits are operating satisfactorily under these conditions at the present time. A point worthy of note and which has not previously been mentioned is that the stop impulse in the code adopted for Bell System apparatus is slightly longer than the other impulses, which facilitates the use of regenerative repeaters in tandem without requiring complex speed control arrangements.

General Features of Teletypewriters

Teletypewriters are widely used for high speed written communications. Generally speaking, written communications are desired for purposes of accuracy. Therefore, high speed, accuracy and reliability are basic requirements for teletypewriter service.

In choosing an operating speed at which distributors of teletypewriters are to be set, several factors must be considered. These are the capabilities of the mechanisms of the machines, the average capabilities of operators for continuous sending at high speeds, the commercial need for high speeds, and the capabilities of the line circuits for transmitting the signals reliably over long periods without excessive distortions or excessive attention for maintenance and adjustment. A satisfactory compromise among these different factors seems at the present time to be about 60 words per minute, or 368 machine operations per minute, which is the speed usually employed in the Bell System. The machines themselves may be arranged and adjusted to be capable of higher speeds up to about 75 words per minute, and it may be that, in the future, service at these higher speeds will be justified under certain circumstances.

Accuracy and freedom from breakdown troubles are necessarily inter-related and both required to a very high degree for machines handling important written communications over long distances. To give some idea of the severity of these requirements, we have found from long experience that to produce a good machine we can not be satisfied in our laboratory tests unless the machine is capable of typing at least 1,000,000 consecutive words (6,000,000 operations) without

error or trouble of any kind, and without requiring service attention of any kind other than normal replacement of paper and inking ribbons.

For rendering service economically with teletypewriters on subscribers' premises, an important requirement in order that the expense of maintenance be not prohibitive is that the machine should not require maintenance attention except at very infrequent intervals. Bell System machines are designed to require routine maintenance attention not oftener than once in two months where the machine is used continuously over periods of eight hours each day. To accomplish this the problem of lubrication has required very careful attention. It has necessitated the provision of oil reservoirs in certain places and the careful selection and specification of oils and greases. Another feature making for economical maintenance is interchangeable parts. In other words, if a part breaks or wears, it is replaceable by another part of the same type without requiring fitting and usually without readjustment.

At times customers wish to use teletypewriters on tables especially designed and arranged to suit the convenience of their offices. For this reason teletypewriters are designed as far as feasible to be self-contained units which can be mounted on any desk or table.

All present Bell System teletypewriters employ the start-stop system of synchronizing and are well adapted for the connection of any number of machines to one circuit with facilities for rapid to and fro intercommunication among the various stations. To permit optimum control of intercommunication and interruption of the sending station when desired, a device known as the "break lock" is incorporated in many machines. This device, together with a "break" key located on each machine, provides facilities whereby any station may interrupt a station which is sending, take control of the circuit and send. The operation of the "break" key opens the line transmitting a signal which causes the "break lock" device to function at the station which is sending and automatically stop any further sending from that station until the device is manually restored. This device is very important in the case of transmission from a perforated tape, which is described later.

Motor control devices are of importance for stations which are not in continuous use but which may wish to receive messages from time to time from distant stations without requiring an attendant to turn on the machine. Such devices are used both in private line and in TWX services. In the case of a private line it is often desired to have the machine normally idle with the motor stopped but so arranged that,

when a distant station wishes to send a message, a signal may be sent which will automatically start the motor and condition the receiving machine so that it will properly record the message and then have its motor automatically stopped again at the end of the communication. Various devices are available for this purpose, some operating over the regular signaling circuit and others requiring a separate circuit. Similarly, in the case of TWX service, stations may, if desired, be equipped for unattended service so that, if the station is called and no attendant is present, the teletypewriter motor may be started remotely by the switchboard operator and the station conditioned to record the incoming message at the termination of which the motor can again be stopped by the switchboard operator.

Signal bells are usually provided on the machines so that, if it is desired to call an attendant to a working machine or to call attention to a specially important message being received, the bell can be rung by signals sent over the circuit.

A general feature incorporated in the design of all modern machines, and one which is not often appreciated, is the so-called "overlap." This feature makes high speed possible by overlapping the selecting and printing parts of the receiving operation. In other words it provides for the typing of one character to take place simultaneously with the reception of the selecting impulses for the next character.

Features of Page Teletypewriters

Page teletypewriters have been built in several different forms, notably with a moving paper carriage or a stationary paper carriage and with a typewheel or with type bars for printing. An early design employed a moving paper carriage and a typewheel, with an ink roller for inking the characters on the wheel. With this design it was impractical to make satisfactory carbon copies, the printed record was unevenly inked, and much trouble was experienced due to side printing, that is, unwanted printing of portions of letters adjacent to the desired letter on the typewheel. Furthermore, considerable trouble was had in properly feeding paper from a paper roll through the moving paper carriage.

To eliminate these limitations and troubles it was decided that for general service in the Bell System a new machine should be designed to be capable of making as many carbon copies as a typewriter and that it should use type bars and have a stationary paper carriage. This sort of machine was new in the art and required extensive development work to produce a satisfactory commercial design because of the in-

herent difficulties of moving an automatically operated basket of typebars back and forth in front of the stationary paper. The present standard No. 15 teletypewriter was the ultimate result of this work and has proved very satisfactory in general service over a number of years. It employs a typewriter ribbon for inking, has the paper roll inside the machine cover and makes very satisfactory carbon copies with various types of paper supply without being subject to the paper feed, inking and side print troubles previously experienced.

This machine has also lent itself to meeting later demands from business houses for typing either single or duplicate copies on special printed forms as commonly used in modern business practice. By equipping the platen with sprocket teeth and having feeding perforations along the edges of the forms, all copies of these forms are automatically held in perfect registration during typing at all stations connected to the circuit. In connection with the rapid handling of these forms a further requirement for automatic tabulation has been met by providing a tabulating device which on the transmission of a certain signal causes all carriages to move over rapidly to any predetermined position on the form and stop there for the typing of letters or figures in columns perfectly aligned. This device greatly facilitates the rapid transmission and reproduction of orders and the like on organized printed forms.

With the advent of TWX service a new situation arose in which many of the machines were only infrequently used and then for very short periods to make a single copy only. To render this service economically it seemed desirable to have a less expensive machine and since narrower capabilities were required this seemed entirely feasible. Accordingly a new machine known as the No. 26 teletypewriter has been developed primarily to print a single satisfactory copy although one carbon copy can be made if desired. To obtain low first cost this machine has a moving paper carriage and to secure a satisfactory printed record it employs ribbon inking and a typewheel arrangement which is a sort of cross between conventional typebar and typewheel designs. This typewheel is an assembly employing a small individual type pallet for each separate character. In the process of printing a character, a striking arm somewhat like the shank of a typebar comes forward and forces the individual type pallet against the ribbon to make an impression on the paper. The typewheel is rotated to different positions to select the different characters to be typed. In this way satisfactory inking and a clear cut impression without side print is obtained, which compares favorably with the record obtained

on a typebar machine or typewriter. The entire machine costs appreciably less than the more comprehensive No. 15 machine. The No. 26 machine is illustrated in Fig. 7.

Fig. 7—No. 26 teletypewriter.

Features of Tape Teletypewriters

In the case of tape teletypewriters it is also necessary to have a clean printed record and occasionally there is a need for carbon copies. Accordingly, the tape machine standard for the Bell System is a typebar machine using an inking ribbon and known as the No. 14 teletypewriter. It is illustrated in Fig. 8.

A feature worthy of note is that with this machine typing always occurs at the same point introducing a problem in connection with platen wear. If the platen were fed by the usual ratchet in, say, 36 steps per revolution, there would be heavy wear concentrated at these 36 points and the platen would require frequent replacement to pre-

Fig. 8—No. 14 teletypewriter.

serve good printing. To avoid this, the platen is fed through differential gearing so that on a second revolution the typing comes in a different spot from that of the first revolution; thus the wear is uniformly distributed over the entire circumference.

One carbon copy can be made by leading tapes through the machine from two rolls of record paper and one roll of carbon paper. Two carbon copies can be made in a similar way if desired.

The tapes employed may be either gummed on the back for convenient pasting on blanks for filing or may be plain paper tapes if the records are of temporary interest only. Also cellophane or similar transparent tape may be used if it is desired to project the record on a screen. A tape out signal is provided on the machine so that when a roll of tape becomes nearly exhausted a bell will ring continuously to give warning of this fact. Where a bell is not desired, the last few feet of tape on the roll are painted red to give similar warning.

If desired, this tape printing machine may be used on the same circuit with page printing machines such as the No. 15 teletypewriter, and when so employed is usually equipped with an "end of line indicator" to warn the operator of the approach of the end of the line in the page machine, so that suitable signals may be sent for starting a new line.

Features of TWX Switchboard Operators' Teletypewriters

Such machines must be small in size to permit their use in a switchboard position, quiet in operation to permit their use in the same room with a telephone switchboard and must be capable of working with any machine employed in the TWX system.

To meet these requirements the standard No. 14 tape teletypewriter has been modified in several important respects as follows:

1. It has been provided with a specially designed enclosing cover which reduces the machine noise radiated by at least 5 db more than standard covers.

2. The machine is tilted so as to raise the keyboard and permit the operator to assume a more elevated position nearer the switchboard jack field.

3. It is equippent with an end of line indicator mechanism and lamp to warn of the approach of the end of a line when sending to a page teletypewriter station so that the proper signals may be sent to start a new line.

4. The usual tape feeding mechanism which pulls the tape past the typing point and obscures some of the typed message is replaced by a so-called "push feed" mechanism which acts ahead of the typing point and makes the typed message more fully visible.

5. Many of the operators' machines are provided with specially arranged power supply and governing circuits so that their motors normally run from 115 volt a-c. commercial supply but in case of a power failure can be quickly switched to run from the 130 volt d-c. telegraph battery.

Features of Monitoring Teletypewriters

In connection with private wire teletypewriter service it has been found very desirable to have so-called monitoring teletypewriters in the repeater offices to facilitate testing between offices and with the subscriber stations. These machines must be adaptable to work with any subscriber's machine and to be usable for making test measurements on circuits.

The No. 14 tape teletypewriter has also been adapted to this service. It may be equipped with an end of line indicator to facilitate communication with a page teletypewriter. Also since commercial service is given at speeds of 40 and 60 words per minute, many of the monitoring machines are equipped with two-speed governors and a switch to provide for changing from one speed to the other. These machines are also usually arranged for normal operation from commercial power supply but emergency operation from the 130-volt telegraph battery.

For making test measurements over circuits a special orientation scale is provided together with a small crank extending through the cover for quickly shifting the orientation setting to any desired point. With the machine carefully adjusted to be practically free of harmful distorting effects on the signals, it may then be used for measuring distortions in received teletypewriter signals, the scale being arranged to read the total distortion directly in percent of a pulse length.

Tape Storage Transmission

A heavy volume of traffic may be transmitted rapidly and conveniently by the use of perforated tape. In this method a machine known as a perforator and having a keyboard like that of the teletypewriter is used for punching the code signals for the message in a strip of paper tape. This may be done with simultaneous typing of the message on the teletypewriter in which case the speed of perforating is limited to the speed for which the teletypewriter is set. If a typed record is not made simultaneously with the perforating, punched tape may be prepared at practically any speed within the capabilities of the operator. This punched tape may then be fed through a device known as a tape transmitter which automatically transmits the message signals from the tape at the maximum speed for which the teletypewriters connected to the circuit are set, which is usually 60 words per minute.

The method of transmitting from perforated tape has the distinct advantage of using the line at maximum efficiency at all times as compared with direct keyboard sending where pauses in operating the keys

and interruptions to the operator result in direct losses of circuit time and effectively slower transmission.

Another important advantage of the perforated tape method is that errors may be corrected in the tape before transmission with the result that only errorless copy is transmitted on the circuit. This is done in the following manner and is illustrated in the section of perforated tape shown below. If the operator in attempting to write the word THE should strike the keys T and J (in error), realizing her error she back spaces the tape one division, strikes the "letters" key and then the correct keys H and E. The transmission of the "letters" signal will cause no operation in the recording teletypewriters since they are already in the "letters" case, and the word will be recorded correctly as though no error had been made. Similarly, entire words or groups of characters may be erased from the tape if desired.

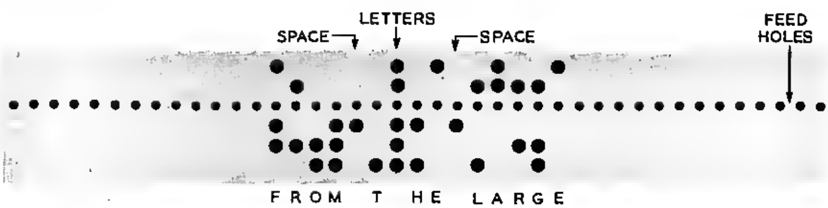

Fig. 9—Sample of strip of perforated tape.

For TWX service a further advantage of the perforated tape method is that the entire message may be punched in tape and checked by printing, if desired, before a call is placed and a connection established. Then, when the connection is established, the message can be automatically transmitted at maximum speed requiring a minimum time for the connection and giving a minimum charge for the call.

It is true, of course, that in this method there is some delay between perforation and transmission. For this reason short to and fro messages, as required in setting up a connection, may be better handled by direct keyboard. To facilitate such working, the perforator keyboard is normally arranged so that by throwing a switch this same keyboard may be used for direct keyboard sending without perforating. This switch also has an intermediate position in which the keyboard is connected for simultaneous direct sending and perforating. This provides for meeting the needs of certain TWX subscribers who wish to simultaneously type and punch the message so that the typed copy may be checked as it is perforated.

The complete page printing set arranged for tape transmission is

known as the No. 19 teletypewriter set and is illustrated in Fig. 10. It employs a No. 15 teletypewriter as the page printing unit.

Fig. 10—No. 19 teletypewriter set.

Automatic Retransmission Using Reperforators

At times it is desirable to retransmit messages received from one circuit to some other machine or machines on a separate circuit. A unit known as a "reperforator" is often used to facilitate such retransmission. The reperforator now standard for the Bell System is a start-stop receiving device using the 5-unit permutation code. It is somewhat similar to the receiving-only tape teletypewriter except that the record produced consists of code perforations in a tape rather

than typing on a tape. This perforated tape is the same as tape produced by a keyboard perforator as previously described, and may be used in an automatic transmitter for retransmitting the message on a separate circuit. The reperforator is usually associated with a receiving teletypewriter on a circuit and may be cut in or out manually or automatically from signals transmitted along with the message signals, so that it will automatically reproduce a code tape for use in automatically retransmitting such messages as desired on some new connection.

Conclusion

The fundamentals of teletypewriters, as described above, now seem to be fairly well established. The future should bring simpler and cheaper machines, especially where the more difficult requirements do not have to be met, and probably additional attachments and auxiliary features to extend the applications and convenience of operation.